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THE DRAINAGE OF THE VALLEY OF MEXICO.

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Three years ago, on my return from Paris to Mexico, I had the pleasure of addressing the members of the American Society of Civil Engineers upon the transactions of the celebrated Congress at Paris, on the subject of Interoceanic Canals, at which Congress I had been a delegate from Mexico. Now, during a short visit to the United States, I am asked to give some information in regard to the drainage of the Valley of Mexico, or rather with regard to the different projects that have been or are being more or less put in execution to carry out that great work.

That work is of local interest to Mexico, but I see with pleasure that what interests Mexico also interests the United States. Great enterprises are being organized in Mexico with American capital and under American engineers, and although most of the works there undertaken are in connection with railway interests, no doubt by degrees other great enter-

prises will be formed, and we will see American conjointly with Mexican engineers working upon those improvements which will make Mexico a great country of the world, as the United States is now, owing to the wonderful development of its public works.

The question of the drainage of the valley is very vast, and it will be difficult in one session, particularly without documents and necessary papers, to give you a full account of the subject; nevertheless I will endeavor to recall the principal data.

At the moment of leaving Mexico I received a request to be prepared to give information on this subject, but I had only time enough to pick up one or two maps to illustrate the question to a small extent. It would have been well to have brought many other papers, but they were so numerous that it was almost impossible to do so; so I will speak from memory.

The Valley of Mexico is one of the points on the surface of the globe that have a special individual interest; it is a peculiar valley, which, on account of its geological formation, will always attract the attention of geographers and engineers. It can be compared only with certain basins occupied by seas or lakes in the interior of Asia, as, for instance, the great Caspian Sea and other interior seas or lakes, which are similar to the Valley of Mexico in this respect, that they have no exterior outlets. It is in this respect also similar to the Great Salt Lake Valley in Utah. But the Valley of Mexico has attracted attention chiefly on account of the City of Mexico being built in it, on the border of the Lake of Texcoco, generally known abroad as the Lake of Mexico. If the Valley of Mexico had not been the seat of the capital of a large state, the valley itself would have passed almost unperceived or unnoticed, and the work of nature and time would have sufficed in this, as in other similar cases, to realize in the course of ages the drainage (*desagüe*) which in this case has occupied so many generations.

The general form of the valley is elliptical. It is situated at the crossing of the two volcanic lines that traverse that part of the North American Continent from north to south and east to west, and may be considered as an immense volcanic mouth. In its borders as well as in the interior of it there are a considerable number of extinguished craters. That of the Popocatepetl, the greatest of all, is the only one still in activity. The valley is shut in on all sides by high mountains, some of them covered with perpetual snow. The Ixtacihnatl and the Popocatepetl,

the highest, rise above the level of the sea, from 15 000 to more than 18 000 feet. The table-land at the bottom of the valley measures more than 60 miles from northwest to southeast, and about 30 miles from northeast to southwest. The general direction of "*thalweg*" follows the main direction of the mountain chains that enclose it; that is the same of the Sierra Madre chain, but the waters that flow in its basin are stopped toward the north by the small rocky peak of Cittaltepec and its slopes, running east and west, which are composed of hardpan (*toba*, *tepetate*). The basin thus formed receives the waters of all the watersheds of the valley, the surface of which measures more than 2 500 (two thousand five hundred) square miles. Nevertheless the rain that falls on that immense surface hardly suffices to feed the lakes which occupy the bottom of the great hollow in the basin of the valley. With the waters is swept the detritus of the mountains, which constantly fills the lower points of the surface, gradually leveling all the asperities of the ground. Abandoned to the course of time and to the free action of the elements, it is probable that the bottom of the valley, after a long geological period, would have been raised by this detritus to such a height that its waters would have overcome their barriers and, through the Mocteruma River, would have flowed to the Gulf of Mexico.

At present the table-land of the valley is mostly occupied by different lakes. (See the map, Plate XIV.) The principal one, and the lowest of all, is Lake Texcoco. Besides that lake there are, toward the north, the lakes of San Cristobal and Xaltocan, whose waters communicate freely and may be considered as one; they are 10 or 11 feet above the level of Lake Texcoco. Further to the north is the small Lake of Zumpango, 24 feet above Texcoco. Toward the south are the two other lakes of Xochimilco and Chalco, separated only by a causeway under which the waters flow. These lakes are 10 feet above Lake Texcoco. The extent of surface occupied by these lakes varies greatly according to the season of the year. Texcoco has from 10 to 20 square leagues; San Cristobal and Xaltocan from 4 to 8; Zumpango only 1 league, and Chalco and Xochimilco 8 leagues. The regimen of the waters of the lakes, as can be seen by these data, is subject to great changes. The three upper lakes toward the north receive in their respective basins the waters of different small torrents that bring water only during the summer months, and consequently these lakes, that have only a maximum depth of water of from 6 to 8 feet, become in time of drought almost dry. The lakes

on the south are quite different; they are fed chiefly by numerous springs in their beds or on their borders, the product of the snows that cover the summits of the encircling mountains; consequently they are permanent, and have from 8 to 10 feet of water, and even more. Their overflow runs by a wide canal into Lake Texcoco; their water is fresh and potable, whilst that of the northern lakes is brackish, owing to their being stagnant, having only an occasional flow through sluice-gates into Lake Texcoco. This lower lake receives as a last collector the floods of all the principal streams of the valley and the drainage of the plain and of the City of Mexico. Having no outlet, it is in direct communication with the subterranean waters (*eaux ambiantes*) that pervade the whole extent of the lowlands, composed of the washings from the mountains. In the city those waters are to be found 3 feet below the surface of the streets and, like those of the lake, are salt—another lake, invisible, over which the city sits.

A MEMBER.—Is Lake Texcoco salt now?

Mr. DE GARAY.—Yes, it is so, and its waters are becoming salter every day. It is a well-known fact that lakes that have no outlet for their waters are all salt. The composition of the salts contained in them varies according to the nature of the ground in which they lie, and which depends upon the decomposition of the rocks that form the geological structure of all the region. Sometimes those salts will be of carbonate of lime, or carbonate of magnesia, or carbonate of soda, or of other bodies, and being soluble, are washed down constantly to the plains, enriching the soil and giving it the necessary elements required for organic bodies. The excess of the salts is swept down by the rains and the rivers into the lakes and into the sea, where they have been accumulating from the beginning of creation. When the basin that receives the water is of small capacity, like a lake, and if it has no outlet, the waters become more and more saturated with the salts. The causes indicated above have produced great changes in the Valley of Mexico since man first appeared there. All the Indian traditions speak of different tribes all coming from the north. On reaching the valley they all stopped and settled, until they were dispossessed by the invasion of some new nation. The land must then have offered great attractions for wandering hunting tribes, which were guided in their peregrinations by the necessity of following the herds and flocks from north to south, according to the season of the year. The valley for them was an Eden, vast, well wooded, full

of springs and running waters, with lakes and marshes, full of all kinds of game. The prize was worthy of a struggle for its possession, and tribe succeeded tribe, until the Aztecs appeared. They were great warriors. When they first came, toward the beginning of the fourteenth century, they were but few in number, and they readily accepted the sovereignty of the Acolhuas, who were masters of the land, and who had made some progress in the arts of civilization. As they increased, and as their reputation for bravery was well established, their lords, afraid of their superiority, dispossessed them of the land, and obliged them to seek refuge on some small islands in the western part of the great lake. There the prophecy of the Aztecs was fulfilled; according to it, they were to be a wandering tribe and outcasts until they should see an eagle perched upon a cactus tree, with a snake in its beak. The vision took place, and from that moment the seat of a mighty empire was established on a small rocky island. It was at that time that the Aztecs changed their name as a nation, and were called henceforth Mexicans, from the name they gave to their new capital, Mexico. The eagle with the snake was adopted then as their blazon, and it is so to the present day. We are obliged to occupy your attention with some historical facts of that people, that are intimately bound up with the subject of the drainage of the valley. From the moment that the first Indian hut was raised on the lonely island in the middle of the lake, the great problem of the drainage of the Valley of Mexico was put forth; its solution was imposed on future generations.

The Mexicans gradually became masters of the whole land. Soon they found, however, that the precarious residence that they had fixed in the middle of the waves was good as a refuge against their powerful enemies, but full of dangers and inconveniences for a quiet home. They had to suffer constantly, more or less, from inundations, many of which are recorded in the annals of their history. From that early period they began to raise dykes and causeways in different parts of the valley. But the work that is worthy of the admiration of modern generations, is the great dyke built some 100 years before the conquest, under the reign of Moctezuma Ilhuicamina (called the old), by his nephew Nezahualcoyotl, King of Texcoco, renowned for his wisdom as a legislator and as a poet, but more worthy of praise, in my opinion, as a great engineer. After having suffered the disaster of a great flood, the Emperor of Mexico called to his help his nephew, the King of Texcoco.

Nezahualcoyotl came with 20 000 Texcucans, and undertook the building of a great dyke 8 miles long, extending from north to south, from Atzacoalco to Iztapalapam, passing 2 miles to the east of the city, and dividing the great lake in two parts ; the eastern one took the name of Lake Texcoco, and the western one that of Lake of Mexico. The dyke was built with rubble-stone and crowned with masonry. By means of that dyke the city was saved from the danger of the waters that entered Lake Texcoco, coming from the Cuautitlan River, towards the north, that used to cause its principal floods. On the other hand, the fresh waters from the southern lakes of Chalco and Xochimilco continued to pour into the Lake of Mexico, washing the suburbs of the city and, through sluice-gates under the great dyke, establishing a current toward Lake Texcoco. In this way a sweet-water lake was created around the capital, and beautiful gardens were to be seen on every side, and not only on the mainland, but floating gardens, loaded with flowers, covered the surface of the waters, and rendered the residence of the Moctezumas a most enchanting place. The great dyke toward the south ended at Iztapalapam, a large place, the residence of Moctezuma's brother at the time of the conquest, and celebrated for its magnificent gardens. Just above rose the isolated peak or high hill of Citlaltepec (Star Mountain). The name, no doubt, was given to the peak on account of the holy fire that was perpetually burning in a great temple built on its summit. It was the belief of the Mexicans that the world would cease to exist at the end of one of their cycles, which were of 53 years. After the setting of the sun at the end of each period, all the fires of the empire were extinguished and the night was passed in prayer and ceremonies, many fearing that they had seen their last sun. The new dawn was anxiously expected, and as soon as the rising sun appeared above the horizon torches lighted at the holy fire were carried by couriers throughout the land to California down to Guatemala to light anew the fires. They felt then that another cycle was assured. The temple has disappeared, the holy fire has been extinguished long ago, and the sun has continued on its course, but what is to be regretted is that Nezahualcoyotl's great dyke has been abandoned and allowed to fall to ruin shortly after the Spanish conquest. The new-comers never understood its great usefulness, and to this day no historian has rendered Nezahualcoyotl the praise that he deserves for his great work. With its ruin the danger of inundation returned, the salt water invaded the land,

the gardens gradually disappeared, and where for years flowers grew are now to be seen ruins and arid lands. The waters of Lake Texcoco have receded, but the waste extends its circle every day. As a confirmation of what we have stated, we have only to read in Cortez's letters to the Emperor Charles V. the glowing description of the valley and of its riches and population. With regard to its topography and waters, he says that the bottom of the valley was occupied by two great lakes, the one to the north, of salt water, and the other to the south, of sweet water. Those lakes were the Texcoco and the Chalco and Xochimilco, that may be considered as one. He makes no mention of the lakes of Zumpango, Xaltocan and San Cristobal, because those lakes are mainly artificial and were then less important than they are to-day, being at that time chiefly marshes formed by the waters of the Cuautitlan River, that poured its flood over the plain. When Cortez arrived the slopes of the mountains were covered by cedar trees almost to the water's edge, the climate was milder than in our days, and the seasons were more regular. After the Spanish conquest the forests were cut down to a great extent, in order to rebuild the capital and all the other cities and villages that had been detroyed during the war. The woods were burned, as they were a refuge for the enemy and for wild beasts. Gradually the cedars disappeared, leaving in their place a less luxuriant vegetation. The slopes of the hills, unprotected by the trees, were cut into ravines by the rains, and all the sedimentary matter swept by the streams was carried to the lakes, where it settled, filling up their basins very quickly. As their beds were raised the waters extended their area and periodically flooded the city. To avoid those evils, new dykes were raised in every direction, dividing and separating the currents in the whole extent of the valley, stopping their flow and converting them into stagnant waters. Public health was not a matter of great consideration in those remote times. The only thing that occupied the mind of the rulers of the land was the danger of inundation, and the great fear that possessed them made them forget that water is a most necessary element of life. All their efforts were bent in discarding what they considered their enemy. As early as 1580, less than 60 years after the conquest, general surveys were made of the valley with the view of opening a direct outlet for the waters, abandoning the negative system of drainage by means of dykes that had been followed until then. The Indian traditions and projects were examined, but the magnitude of the enterprise and the novelty of the works para-

lyzed at first all resolution. 25 years later, under the pressure of new calamities, a great effort was at last made, and a man of genius and great resolution appeared, disposed to take upon himself the responsibility of forming and executing the plan so long desired. That man was Enrico Martinez. He was known as a cosmographer, a mathematician and a printer. His project had in view the free flow of the waters in the valley, based upon the opening of a tunnel that would permit at will the flow of all the lakes through the range of hills that closes the valley toward the north. Enrico Martinez had to submit his plans to the examination and discussion of a congress (*junta*) composed of all the principal men of the city, counting amongst its members the Archbishop of Mexico, the heads of all the religious communities, and the military commanders. Enrico boldly proposed the construction of a tunnel 5 or 6 miles long—a thing never thought of at that time. He demonstrated that no country in the world had then the means that Mexico offered to carry through the work—experienced miners and cheap Indian hand labor. The tunnel was adopted, but at the same time his plan for the general drainage of the valley was rejected as utterly impossible. It was alleged that the ground did not offer sufficient fall for the outlet of the waters of Lake Texcoco. Their objection was based on the saying of Pliny, that water to run needs half a foot in one hundred. Enrico Martinez was on that account constrained to limit his project to the drainage of Lake Zumpango, into which all the waters of the River Cuantitlan were thrown. This river was the principal of the whole valley, and its floods the main cause of the inundation of the city. Accordingly the flow of its waters was stopped by a dyke below Zumpango, and the lower lakes of Xaltocan and San Cristobal, deprived of the affluence of its fresh stream, became salt marshes and their once fertile shores sandy plains. The plan once formed, Enrico Martinez carried out the work with surprising activity. In the short period of 11 months he made the excavation of the subterranean gallery, more than 6 miles long. At the same time he reinforced the dyke of San Cristobal, 3 miles in length. The celerity of the work did not argue for its perfection. The tunnel was 10 feet wide, and was opened in a formation of hardpan (*tepetate*), with strata of sand and marl and without revêtement. It was opened in 1608, and had hardly been finished when it was put in use. Shortly afterward a temporary facing was put on it of timbers, and soon afterward one of masonry. The work of consolidation had not been finished

when a great flood came ; the tunnel, from unknown causes, was obstructed, the upper lakes were filled, the waters poured over the dykes, and the City of Mexico was once more totally flooded. It remained so during four years, and all that time the engineer was kept close in prison. The city was almost ruined, and its white population reduced to about 2 000 souls. When at last, after some earthquakes, the waters receded, a great but unfortunate resolution was taken ; it was decided that, instead of repairing the tunnel, an open cut should be made in its place. Enrico Martinez, taken out from his jail, was ordered to execute the monstrous work. He died at his task, after 35 years' labor ; others succeeded in his place, and for a century and a half the great cut of Nochistongo was the main occupation of the inhabitants of Mexico. The work, modified by nature, was at last finished as it now stands. At first sight it looks as a natural ravine. The constant land slips have modified its side slopes, and the stream describes in the bottom a series of capricious curves. It is the largest cutting known to have ever been made in the world. It has in its greatest depth 200 feet ; in the beginning it had more, but in the course of time it has been partly filled. The inclination of the sides is also quite irregular, on account of the washing of the soft strata and of the decomposition of the marl beds, that leave undermined the upper formations, that are constantly falling in. The cost of that immense work cannot be estimated. In silver alone the disbursement was more than 6 000 000 dollars, but in those times it must be borne in mind that the journeymen were paid from 9 to 12 cents a day, and that most of the workmen in the *desagüe* (works of drainage) were sent or brought in gangs from the neighboring villages at first, and afterward from other places like Tlaxcala and Cholula, 50 and 100 miles distant, to work free, in discharge of the task imposed on them as a debt. Besides those hands, all the convicts to hard labor (and they were not few) were sent to work out their sentence in the Great Cut. Once there, they were doomed to the greatest dangers and hardships, and the loss of life was really awful. The writers of the times estimate that from 100 000 to 200 000 Indians perished in that rash undertaking. At the same time that the waters of the Cuantitlan River were taken out of the valley by the new cut toward the north, the waters that flowed from the lakes on the south were kept enclosed by the dyke of Mexicalimgo, through which only a narrow passage was left them. The waters, retained by sluice-gates, gradually rose

in the lakes of Chalco and Xochimilco. They actually cover the pavement of the streets of the old village of Tlahuac, situated between the two lakes, with 5 feet depth, and it would have disappeared under the waters if the greater part of its houses were not established on the *chinampas* (floating gardens). As the waters have risen, their pressure has increased on the springs in the bottom of the lakes, and their delivery has diminished greatly. I have been in a situation that has enabled me to make a curious experiment on those waters. In 1865, when one-half of the City of Mexico was flooded, and a total inundation of it was considered certain, I was called by the Government of Maximilian to avert the danger, and full powers were given to me. That was a critical moment. I had refused all connection with the invaders of my country, but those that were in peril were my fellow creatures and my fellow citizens, and I accepted—on condition, however, that I would be allowed to work without any official title, as a private engineer, and without any compensation. With that understanding I set to work. Amongst other things, I built a dyke 2½ miles long and 7 feet high at Culuacan, stopping the outflow of all the waters in the south of the valley toward the Lake of Texcoco and the City of Mexico more than 50 cubic meters a second. I had a terrible struggle at first with the waters, raising my dyke as the waters rose, and spreading them over the Lakes of Chalco and Xochimilco, and the lowlands, on a surface of more than 60 miles. 20 square miles more were expected to be flooded, and Chalco, Xochimilco, Tuyahnalco and a dozen more villages on the borders were doomed to destruction. For the first time in the history of the country, the outlet to the southern lakes had been closed, and great calamities were predicted by many on that account. The waters, it was said, would rise with fury ; the springing fountains would overturn all obstacles and rush down on the capital, sweeping everything on their way, until the immense reservoir of 80 square miles surface would have emptied its contents. In spite of all opposition, I persisted in the plan I had traced, and the results were astonishing. To the rushing waters I opposed their own pressure, and, long before I expected, they ceased flowing. The repressed waters of the lakes rose 2 feet above their former level, and for 4 months their level remained invariable, almost motionless. Toward the month of July, with the rains, their level began to rise again, until in October they had risen 4 inches more. After the rainy season their level decreased the same 4 inches, and

continued motionless for all the dry season, the springs furnishing only the necessary water to maintain the hydrostatic equilibrium, repairing the losses due to evaporation and infiltration. The Lake of Texcoco, deprived on every side of the waters that used to feed it, began to decrease, the flood retired from the streets of the city, and Mexico was saved from the horrors of an inunda .on that would have caused its ruin. For doing that work I was criticised and abused by certain politicians and by many persons whose interests were opposed to the public welfare, although they could see that I was a loser by it also.—No matter; I saved thousands from distress and misery, and I consider that is the brightest page of my life. The experiment to which I alluded, and which I have just described, I think has never been tried before by other engineers, at least on the vast scale on which I worked, probably for the want of a field of operation. To check an inundation by flooding appears rather a novel scheme, and to exhaust large fountains that never fail by means of their own head of water, may seem at first sight rather difficult; but in this case it proved the most feasible and effective.

The work begun in 1608 by the unfortunate Enrico Martinez, it may be said, was never properly finished, and to this day requires constant care and labor to keep it in tolerable service. The flushing of the waters of the Cauntitlan River are not sufficient to keep the bottom of the cut clear of the *debris* that are constantly falling in, and the bed of the river that flows in it was soon raised so much that the waters of the Lake of Zumpango with difficulty could find their way out through it. Besides all the western part of the lake, one-half of it was filled by all the sand and sedimentary matters brought by the floods of the Cuantitlan, and the area of deposit for its waters was so much reduced that it was a constant danger for the capital. At the end of the last century, wishing to improve that state of things, it was resolved that the canal *vertideros* (canal waste), through which the lake emptied its waters into the cut, should be abandoned as useless, and the new canal of Guadalupe consequently was opened lower down. This work proved a new failure. It was about 3 miles long, and on its course intercepted all the surface water and torrents from the Jalpa hills, that formerly came down to the Lake of Zumpango, where they quietly spread in the basin and flowed gradually out, with all the waters accumulated, through the waste canal (*vertideros*). The Jalpa torrents in the heavy summer rains swept down a large amount of stones and rubbish of all kinds into the bottom

of the cut, where they met the moderate current coming from the lake. The velocity of the water was suddenly checked, and a large deposit formed back towards the lake by the matter they held in suspension, as they had no longer force to carry the sediment. The outlet for the waters of the Cuantitlan River being stopped, they receded from Lake Zumpango down to San Cristobal and to Texcoco, putting in great danger the City of Mexico. To obviate this, the Guadalupe Canal was suppressed, and a new canal was opened to connect directly the Cuantitlan River with the cut of Nochistongo. The Lake of Zumpango remained isolated from the river.

In spite of all the works, the City of Mexico remained exposed to inundation. The failure of any dyke, or the overflow of the lakes and rivers, brings all the waters down toward the capital, and the danger increases greatly in the years of heavy rains. The point where the Cuantitlan River crosses the plain, on the slope of the ground, in a distance of about 5 miles, its bed is formed between two embankments 15 or 20 feet high, that are not sufficient always to keep the waters from pouring over, and this overflow opens sometimes large breaches in them. The waters rush then with great impetuosity, laying waste the whole country, and if the freshet is of long duration they reach the gates of the city, and at times will not stop until the streets are covered.

The periodical repetition of those overflows during three centuries, has always been the occasion of new activity in the works of the *desagüe* (drainage) and of new schemes. At the beginning of this century a new attempt was made toward the final solution of the problem, which can be no other but the drainage of Lake Texcoco. Preoccupied nevertheless with a false idea of economy, and having no expert engineers to direct the works, it was thought expedient and advantageous to continue the old plan, and to complete it by deepening the great cut of Nochistongo sufficiently to allow the waters of Texcoco to flow through it. Past experience was neglected, and the new generation of pigmies, in their ignorance, expected to outdo the Titans of old. They were punished by the result; all their efforts for several years came to nothing. The drift of the rivers brought constantly into the channel new sediment to take the place of all that was excavated, and the waters returned to the normal regimen that they had worked for themselves through the cut. The political events in Mexico during the war of independence postponed all work, and the only thing undertaken was to keep the waters of

the Cuantitlan out of the valley. Nothing serious was attempted until 1856. Owing to the neglect of the authorities, the land and marshes on the west and south of the valley had been freely drained for several years, and all their water sent directly to Texcoco. This lake rose slowly, and at last its waters reached the gates of the city. Prompt measures were then taken, and all the old works of the *desagüe*, such as dykes, sluices and canals, were repaired. I had at that time the direction of the hydraulic works in the south of the valley, and by checking and regulating the outflow of the lakes of Chalco and Xochimilco, I succeeded in reducing Lake Texcoco to its proper limits, and all danger of inundation disappeared.

On that occasion great alarm was felt in Mexico. A board or "Junta" for the drainage and canalization of the valley was appointed, and a prize of $12 000 was offered for the best plan presented for the works. Different projects were made and duly examined, and I was fortunate enough to have the prize awarded to me. In the course of time my project, in whole or in part, has been presented and discussed before the Council of the City of Mexico, assisted by seventeen engineers; before a committee of engineers, presided over by Gen'l Doutrelaine, Chief of the Engineer Corps of the French Army in Mexico in 1865; and before the Emperor Maximilian and all his Cabinet Council and a body of engineers, on three different occasions; it was always unanimously approved. This same thing has taken place in various meetings, the most important of which were those of the second Medical Congress in Mexico, where, out of 60 votes, I had only one against my plan; that vote was Mr. Orozco's; that gentleman has been here, some of your members have met him.

Nevertheless, in spite of all the votes given in favor of my plans, they were postponed, on account of political strife and of the foreign war of the French intervention. But when least expected, the question of the inundation forced itself again on public attention, and the authorities of the new empire had to contend with a new enemy. The rainy season of 1865 was extraordinary in the quantity of water that fell in the Valley of Mexico. In the month of June a gap opened in the right bank of the River Cuantitlan. No great attention was paid to the accident at first, the breach rapidly increased, and for want of energy in resisting the evil, the water ran freely for 52 days. The consequence was that all the upper lakes were filled, the waters poured over the dykes of Zum-

pango and San Cristobal down into Texcoco and invaded the City of Mexico. Nearly one-half of the streets were laid under water, and its level rose to within one foot and a half of the surface of the main square. It was to arrest that inundation that I was called upon, and it is to this occasion that I have alluded a few minutes ago. The damage caused to life and property was very great, and it was once more resolved to put an end to a situation that was being aggravated daily.

In the meantime the flood subsided, my duty was fulfilled, and I returned home in December, 1866. At the same moment, I was again requested by Maximilian's Minister to accept an appointment as Director General of the works of drainage. Again I refused to accept official duties under the empire, and the task of executing my plan devolved upon others.

Much to my regret, I have been obliged to dwell on many points of perhaps little interest to you, but on which I have thought it was necessary to touch, even if it was only briefly. I regret also that want of time and the fear of tiring your patience will not allow me to entertain you with many most interesting details concerning the great Valley of Mexico and the works constructed there. But I must now give you a rapid sketch of the general plan adopted for the drainage or *desagüe* of the said valley. Before doing so, I must set the problem that is to be resolved in a technical manner before your eyes, particularly as to some points, in order to be better understood.

I have called your attention to the rapid changes that are taking place in our valley, partly due to the direct action of nature, and partly due to man. All lakes, and particularly all those that have no outlet, tend to disappear from the surface of our planet. Their basins are being constantly filled by the sedimentary matter that the streams and rivers sweep down and deposit in them, and we have indicated the changes which have occurred in that respect in the lakes of the Valley of Mexico. Let us fix some points. In an excavation made by me in the ruins of the Convent of Santo Domingo, within the city, I found at a depth of 20 feet, 16 feet below the actual level of Lake Texcoco, an Indian pavement made with cement and with a polished surface. Under the pavement to a great depth the ground was pure soft clay ; above it, it was all made ground, formed of débris of all kinds. The pavement must have been made many centuries anterior to the Spanish Conquest; it was the work of the first settlers in the land. The sand employed in its

construction is no longer found in the streams of the valley; it has in its composition a large quantity of pumice stone; perhaps some of the volcanoes that we see now extinct were then in full activity. This case shows that the bottom of the valley has risen considerably, but leaves the question of time undetermined. We must now examine the historical period known to us. At the time of the coming of Cortez, the annual rise and fall of the waters of Lake Texcoco was much greater than now, the lake receiving the waters of the Cuantitlan River, and those from the south in greater abundance. Owing to that cause, the Indian city had to suffer more frequently from inundations, but at the same time less severely than in later times, due to the nature of their habits and buildings. Their temples and principal monuments were on the high grounds of the small islands they occupied, and the mass of the population lived in huts or light buildings on the border of the canals, and chiefly on the *chinampas* or floating gardens. So it happened that when the waters of the lake rose the well-built part of the town was too high to be reached, and the dwellings of the working and poorer class rose at the same time—a floating city.

It is well known that the City of Mexico, surrounded by the waters of the lake, communicated with the main land by causeways, except toward the east, where the dyke of Nezahualcoyotl extended from north to south, and beyond it was the Lake of Texcoco. The waters of that lake, as far as I can judge, must have been from 40 to 50 feet deep in its centre at that time. Cortez, speaking of the lake, seems to consider it as a small inland sea, and in the beginning even thought it was subject to the tides of the ocean, so important did it appear to him. With his great military genius, he at once saw all the advantages he could draw from the deep barrier that defended the city, and, bent on its conquest, and knowing from experience that the attack by the causeways was too hazardous of itself, he determined to make it by a naval force. Accordingly he ordered that all the iron, ropes and timber that had been saved from his vessels, before he set fire to them on the coast of the Gulf, should be taken up inland to the Lake of Texcoco, and with these materials in a short time he had afloat four brigantines. Small vessels they must have been, and too weak to struggle with the fury of the deep, but they sufficed under the mighty hand of Cortez for the overthrow of a great empire.

As a curious historical fact, I may here state that later on the same

vessels, taken to pieces again, were sent to Sihuatanejo and there put afloat on the Pacific Ocean, to continue the exploration of the south coast.

The Lake of Texcoco never figured in history with greater importance than it did at the time of the Spanish Conquest, nor will so ever figure again before its final disappearance. As soon as Cortez had his small squadron of ships ready, he sailed from Texcoco (city) toward the southern extremity of the great dyke, where his great army, chiefly of auxiliary troops, was to join him. A great many canoes accompanied him also. The Mexicans, full of military pride, came out to encounter him, manning thousands of canoes that covered the surface of the lake. When the two enemies were near each other, the wind began to blow from the east, the Spaniards set all their sails out, and their vessels broke through the Mexican line, they firing their guns and sinking the enemy's canoes, killing all those that manned them ; the water of the lake became red with blood. Nor was that the end of the carnage. The Mexicans, sure of victory, had brought with them their wives and children, and had landed them on a steep, rocky island close to the place where the battle took place, so as to make them witness their expected triumph. After their victory the Spaniards landed on the island, and in order to strike terror on their enemies, slaughtered in the most cruel manner all the women and children. The rock is called to this day the Marquis' rock (*Penon del Marques'*), in memory of that bloody battle. The place where that terrible naval struggle took place is now a barren swampy plain.

The shores of Lake Texcoco are now so shallow that its navigation is always very difficult, and it is only made now by a few flat bottom boats 50 feet long by 7 wide, that draw 1½ feet only. The diminution in the depth of the lake during three centuries passed almost unperceived ; no register of it seems to have ever been kept, and the causes of the different inundations were always attributed to the accidents that appeared to produce them.

At the beginning of this century Baron von Humboldt visited Mexico, and in his book on New Spain gives a most interesting historical account of the *Desagüe*. Speaking of Lake Texcoco, he says that its greatest depth is 5 meters (16 feet 8 inches). In our day the greatest normal depth of the lake in the rainy season is 2 meters (6 feet 8 inches). The diminution consequently has been 3 meters in about 75 years.

Baron von Humboldt's statement has been contested by some on the ground that it was given without precision, but in general terms ; but I have been in a position to verify his figures by direct observation of the waters of the lake with reference to bench marks put on its borders and in its own bed. After a series of observations for 14 years, I have found that the mean rise at the bottom of the lake was 4 centimeters ($1\frac{6}{10}$ in.) a year ; that coincides exactly with the 3 meters deduced from the Baron's statement.

In the month of November last year, the point of greatest depth of Lake Texcoco, referred to the Hipsographic monument that exists in the great square of Mexico, as a point of reference for the level of all the lakes in the valley, was 2 meters 80 cent. (9 feet 4 inches) below the surface of the marble slabs of the monument, which are on a level with all the principal streets of the city.

At the beginning of the present century a great number of canals existed still within the limits of Mexico. The rain water and the common sewage ran on the surface in gutters that carried all their filth into the canals, where they remained stagnant and putrid, the canals keeping the same level as the lake. With the city improvements the canals were gradually suppressed and filled, and sewers of small dimensions replaced them as well as the gutters along the streets. All the sewers (that are now become general) communicate more or less directly with a canal or big ditch that runs on the four sides of the city, and that ditch empties on the eastern side through the Canal of St. Lazaro into the Lake of Texcoco. This last canal receives also the fresh water which comes from Lake Xochimilco on the south, which scours to a certain extent the bed of the canal in all its length of 3 miles.

Taking *mean levels*, we have the bottom of the lake, as I said before, 9 feet 4 inches below the general level of the city, the surface of the lake 6 feet 8 inches, the bottom of the sewers 6 feet 8 inches also. The St. Lazaro Canal having a fall from the city to the lake of 3 feet, it follows that at the gates of the city, where it receives the sewage, its level is the same height, at least, *above* the bottom part of the sewers, that have in themselves no declivity, the water running in them with a surface current. This generally is very slow, and when the waters of the canal rise there is a counter current in them, the streets being sometimes flooded on that account. This happens very often, in the rainy season almost daily, and when the level of Lake Texcoco rises 3 feet above mean level,

and even less, the current ceases in the sewers, and there are only fluctuations in the surface of the waters at every shower. The rain water then floods the streets until it disappears, not so much by the drains that are nearly choked, but by infiltration in the ground. This is most effective in a soil where the surface water has only to percolate through a sandy bed 1 or 2 feet thick to join the subterranean waters (*eauxambiantes*) that pervade the whole plain of the valley, and that finally join the waters of the lake. By this description it is easy to see that the City of Mexico has no outfall for its waters; that a great part of the refuse and garbage thrown into the sewers remain and ferment there until taken out by mechanical means; that the scouring of the storm waters is nullified generally by the waters of the Canal of St. Lazaro, that, rising, cover the mouth of the sewers; that the deepest part of the lake is only 2 feet 8 inches below their bottom, and that at a distance of 8 or 9 miles from the city; that the soil being all composed of sand, mud and detritus of all kinds, full of organic matter in decomposition, is furthermore saturated by the infiltrations of the waters of the lakes, of the ditches and of the sewers, making the site of the city a real swamp, consolidated only on its surface by the scorching rays of a tropical sun and a rarefied mountain atmosphere.

The diminution of the rains in the valley, due no doubt to the partial ruin of its exuberant vegetation and the deflection of the river of Cuantitlan through the cut of Nochistongo, as well as the reduction and enclosure with dykes of the fountain springs in the southern lakes, has so diminished its waters that the danger of real inundation is every day less. The gravity of the situation, however, is greater every day. Formerly everybody was afraid of the waves and rushing waters, and to avoid them dykes were made, and the streets of the city have constantly been raised and leveled. But the bottom of the lake rises as rapidly, —$1\frac{6}{10}$ inches every year. The houses of the great city gradually are buried in the mud. Many persons on looking at them believe they are sinking; the result is the same, they tend to disappear, and would do so if they were not periodically rebuilt. But the crisis has now come; the great buildings that were on the most elevated spots have been reached. Will they be allowed also to be swallowed by the wave of mud? If so, before a century passes the halls of the Moctezumas, the palace of the viceroys, the great cathedral, all the great historical monuments, the oldest in the land, will be converted into ruins.

There is still a more important question to consider in the great problem of the drainage of the valley, than the material riches that are in danger—that is the health and life of its inhabitants. At the beginning of the present century, Baron von Humboldt observed with astonishment that, in spite of the marshes and lakes of the Valley of Mexico, malarial fevers were very rare. Unfortunately things are now changed, and malarial diseases are becoming quite common. It is true that the waters do not cover permanently our valley, but they spread stealthily under our feet and rise almost to the surface of the ground to poison the air we breathe. If the water of the lakes and marshes that is constantly fluctuating is injurious to health, the underground water, full of organic matter in a state of decomposition, is tenfold more pernicious. To impress this truth more deeply upon your minds, let me recall what happened in London many years ago, in the time of the great cholera. It was observed that the plague raged with greater fury near the Thames River, and in one district the cases registered were as follows, marking the height above the water:

From	20	to	40	ft. above	65 cases.
"	40	"	60	" "	34 "
"	60	"	80	" "	27 "
"	80	"	100	" "	22 "
"	100	"	120	" "	17 "
"	340	"	360	" "	6 "

It is evident from this statement, that elevation above the river was favorable to life, and that this increased in proportion to the height. Fifty years ago this result was solely attributed to the greater purity that the air generally has in elevated regions, without explaining to what is chiefly due that salubrity. In our day the great progress made in draining lands has given the key to the explanation of that phenomenon, and it is well known that the lower the subterranean water in a region, the healthier it is. In mountain countries this water is sometimes very deep in the ground, and that circumstance contributes to their salubrity. A proof to this effect was made manifest a few years ago in the *commune* of Genenvilliers, where the sewerage of Paris is employed for agricultural purposes. The ground that is abundantly irrigated forms a peninsula on the left bank of the Seine, and the water can naturally drain into the river. Nevertheless, with the establishment of the new culture and the

constant irrigation, the subsoil waters (*eaux ambiantes*) rose in the ground, and immediately the malarial fevers appeared as a consequence. The contrary has been observed invariably in the places where drains have been established. Not only fevers have disappeared or diminished, but likewise all other diseases. In the parish of Bolton, in England, drainage was introduced 35 years ago; the following observations were made:

The cases of fever in August,	1847,	were	30.	
After draining, in August,	1848,	they were	2	only.
In the month of September,	1847,	there were	17	cases.
" the same month,	1848,	" "	7	"
" October,	1847,	" "	4	"
" "	1848,	" "	2	"
" December,	1847,	" "	2	"
" "	1848,	" "	none.	

This needs no comment.

One observation more before I end this exposition. Making a study of the waters of the Valley of Mexico, I could not fail to observe the fountains that spring forth within its precincts. I will make no mention of all those that break out high up in the mountains, by far the more numerous, that are the sources of innumerable rivulets, that are stopped in their descent and their waters employed in irrigation. I will speak only of the springs that burst out at the foot of the mountains, forming in many places large basins (*albercas*), and that are known in the country by the generic name of *ojos* (eyes).

It is worthy of note that in the northern part of the plain or table (*mesa*) of the valley, no springs of any note are found. There is not a single one on all the borders of Lake Zumpango; none on the borders of Lake Xaltocan, and only one towards the northeast of Lake San Cristobal, called simply "Ojo de agua" (water-spring), no doubt for the reason that there is no other spring within many miles with which to confound it. Around Lake Texcoco there are a few *albercas*, the principal ones being those of Chapultepec towards the west, and those of Chimalhuacan towards the east. Almost in the centre is the mineral hot spring of *El Penon*, which has some importance. Passing toward the south, all around the Lakes of Chalco and Xochimilco, and in the bed of those lakes, the spring fountains are almost numberless. But what is most worthy of attention is, that all the springs have an elevated outlet,

that is from 2 to 3 meters (7 to 10 feet) above the level of the city, and from 4 to 5 meters (13 to 17 feet) above the mean level of Lake Texcoco. The water of all those fountains is used in the towns and in the fields as drinking water, and for the irrigation of orchards and gardens, being all in the limits of the plain and with a slope toward Lake Texcoco. We have stated that the bed of that lake rises by the deposits of sedimentary matter 1 inch and $\frac{4}{10}$ths (4 centimeters) every year, and that the City of Mexico, to avoid being covered by the waters, constantly raises its streets and rebuilds its houses. With regard to the town, that is a solution, although a bad one; and that in the end would not save the city from ruin. But the place, for the causes we have developed, will become in the end unfit to live in. If nothing is done to avert the danger (a thing that cannot be admitted), the deposits in Lake Texcoco will have raised its bed so, before a century is over, that all the springs that now give life and health to the valley will have ceased flowing, for want of declivity in the ground to give them current. And this is not an uncertain hypothesis. The springs in the Park of Chapultepec, 3 miles from Mexico, have supplied a great part of the city with water from the time of its foundation. Gradually, as the streets have been raised, the water has lost its ascensional power, and the limits of the distribution of that water have been greatly reduced. A similar thing has happened with the water of the spring of Sancopinca that was used in Santiago Tlatilolco, in the north part of the city; it has ceased flowing long ago, and that great suburb that attracted Cortez's admiration for its fine gardens is now a barren ruin.

At the same time that the springs lose their current for want of fall, their force is also greatly diminished by the diminution of the rains that feed them, and gradually the valley, if things continue so, would be covered with stagnant marshes and barren plains. This cannot, this will not be. If all these evils that threaten are signalized, it is not to strike with terror the population of the valley, but in order to give the word of alarm while there is still time to avert the danger.

Now, what is the remedy? After this long exposition relating to the state of things, the progress of the evil, and its manifest causes, the answer seems to be very easy—the drainage of the valley, the surface drainage, and the subsoil drainage. The Spanish word *desagüe* is applied only to the surface drainage, and, in fact, little or nothing was known about subsoil drainage 50 years ago. To-day the English word

"drainage" has been adopted by us for the subsoil canalization. It is owing to this ignorance of modern methods that many persons willing to admit the *desagüe* as a partial remedy, oppose the subsoil drainage, because they consider it useless, not understanding what it is, nor what it aims at; and here, members of this Society heard not long ago a partisan of those ideas trying to develop a monstrous combination of systems of dykes and big cuttings, with modern schemes of pump sand steam engines.

The plan which I presented many years ago for the drainage of the valley, which was approved and ordered to be executed, and begun with slight modifications in the plan, tends to the total drainage of the Valley of Mexico, of its lakes and of the city. In the system adopted all the waters are utilized, first in the valley, and afterward in the barren lands to the north out of the valley. The Lake of Zumpango in the north, part of the lakes of Chalco and Xochimilco in the south, and part of San Cristobal in the centre, besides other smaller basins, will be utilized for feeding the canals of navigation and irrigation. These canals of small section will be collectors of the waters drained above them until they reach the last collector, which will be the main canal of drainage, located, as near as possible and convenient, in the "thalweg" or lowest level that runs through the lakes from south to north. That great canal has a section of 39 square meters, that is, 10 at the bottom, 16 meters between banks and 3 meters deep. On either side there will be a path 3 meters wide. The canal proper will begin on the eastern side of the city, at the gate of St. Lazaro, and will follow the line of the actual canal N.E. by E. until it arrives near the centre of Lake Texcoco, and then it will turn towards the north, following that general direction across the lakes of San Cristobal, Xaltocan and Zumpango. On reaching the slope of the hills that close the valley on the north, the canal leaves the old line of Nochistongo to the left on the western slope of the Citlaltepec hill, and cuts through its eastern slope under the pass (*puerto*) of Tequisquiac. In that place a tunnel of 8 270 metres has to be opened to the ravine of Ametlac, that communicates with the river or torrent of Tequisquiac. The total length of the canal from the gates of the city to the Tequisquiac River is about 49 kilometres, that is, 30 miles and a half. The fall in the canal will be $\frac{1}{5000}$, and when full it will carry 36 cubic metres a second, with a velocity of 0 meters 89 cent. The tunnel has a chord of 4 metres and 6 meters 30 cent. under the keystone of the arch. Its form is that of a horseshoe, with an inverted arch; its fall is 1 in 1 000 ($\frac{1}{1000}$),

its section about 27 square metres, and, if necessary, more than 40 cubic meters of water can pass through it in a second.

Convinced as I am that, when the drainage of the valley is made, its fertility and vegetation will be greatly increased, and, consequently, that its climate will be greatly modified, making the rains more abundant and regular, I felt disposed, in order to insure a perfect drainage and to prevent accidental inundations, to exaggerate the dimensions and sections of my canals and tunnels. But, on the other hand, sure that with the new system of canalization the waters would be better distributed and advantageously disposed, I reduced my plan and calculations to form a project sufficiently vast to embrace and meet all the points of the problem, giving solidity and durability to the works and security to the inhabitants of the lowlands, that would be brought under culture as a result of the drainage. The meteorological observations that I had at hand with regard to the fall of rain in the valley and the evaporation did not furnish me sufficient data on which to base a good calculation for my works. Neither was it possible to establish *a priori* what would be the infiltrations on the vast surface embraced in my investigations. Consequently, instead of proceeding by comparison with what has been observed and done in other places in the world, so different from ours, and always on a small scale, I resolved to base my work on a grand observation, where all the partial errors of minute and incomplete reckonings would be neutralized, and present a positive and, above all, practical result, beyond doubt or suspicion, and on which I could confidently rest as a solid base for my calculations.

In the year 1856 the City of Mexico was threatened with inundation. The Lake of Texcoco had been receiving for many years an excess of waters from the lakes of the south, and its waters were flooding the lowlands on its shores. I took note of its great rise and extension. I visited all the other lakes, and, admitting the possibility of their being all full at the same time, I calculated what their rise would be, and the volume of water that that rise represented, and added it to the mass obtained from Lake Texcoco. I found the total volume for all the lakes, representing their possible rise in time of partial inundation in all the valley, was equal to four hundred and fifty-three million (453 000 000) cubic meters. I am convinced, and it is easy to perceive it, that that calculation is greatly exaggerated, as the accumulation of water in Texcoco was the result of several years' neglect, and the other lakes had not

the quantity estimated. By proceeding as I did, I had no necessity of taking into account the evaporation of the lakes, certain that the quantity of water evaporated by the vegetation and the ground in the surface now occupied by the lakes will be tenfold greater than what it now is. The infiltrations in a soil comparatively dry will also exceed the losses now experienced in the bed of the lakes. With the increase in vegetation, the waters will be retained on their way down the slopes, and the floods will be of much less importance, having greater duration. All the above reasons convinced me that by adopting as a maximum the quantity of 453 000 000 cubic meters of water to be disposed of, I was sure not to be under the real estimate. Furthermore, I supposed that all that water was the product of a single rainy season, say, of five months, and in order that no danger or inconvenience should accrue for want of a quick discharge of the floods, I calculated my canals and tunnels with such dimensions as to discharge that same amount of water as it arrives, say, in five months, and for that purpose the normal waste has been calculated to be 35 cubic meters a second, but in extraordinary cases the canal, by overflowing the two lateral paths, will carry easily double that quantity, without any risk of causing inundations. It is to be observed that the canal has the same section from the beginning, notwithstanding that the flow of 35 cubic meters supposes that all the waters run together only at the outflow. In fact, it is only at the entrance of the tunnel of Tequisquiac that the current will run with regularity. At the origin the canal will receive gradually only the streams and drains of the lands it crosses, and the section might be in excess, if there was not the possibility of sudden freshets and storms, that for a short time may bring a mass of water into the canal much greater than the 35 cubic meters calculated. The canal, besides, is intended for navigation during most, if not all the year, and its dimensions agree with the size of the boats and the locks and other works in the main canal and in all its branches. It must not be forgotten that, the valley once drained, all the space now occupied by the lakes will be dry ground, and fit to receive the floods of all the streams, which bring down from the mountains large quantities of mould most suitable for the lands. Now the irrigation of the fields by the floods is objected to, for the want of drainage and the fear of inundation, but will be most acceptable as soon as the waters are no longer to be feared. This use of the waters for agricultural purposes will take from the main canal the greatest part of its waters.

The great collector, towards the middle of the bed of Texcoco, has two embranchments of equal section, one for the Lake of Chalco, and another for the Lake of Xochimilco. From this last lake another canal of great importance is directed towards Mexico, where it arrives on its western side, and by a series of canals that embrace the city on all sides will serve to flush the sewers, with a fall of from 15 to 16 feet in two miles. In order to obtain this, as well as the thorough drainage of the ground on which the city stands, the origin of the canal in St. Lazaro is put at its bottom 10 feet below the mean level of Lake Texcoco, and with the fall of the canal towards the north the facilities for drainage increase.

During the dry season water has too much value to waste it, and the great canal, that would then only receive the drains from the sewers of the city, and from the irrigation in the adjoining fields, would not carry a sufficient volume for a good navigation. To meet that inconvenience on the whole line of the canals, locks have been distributed every 6 kilometers, with movable dams (*barrages mobiles*), that will be closed as the necessity is felt and the waters recede. The dams (*barrages*) will be made on the principle of Thénard, Poiré, Chanoine and others, so that they can be shut and opened at will and with great facility. Those *barrages* at the same time accomplish the scouring of the canal by suddenly flushing, by opening them mechanically or making them automatic. In time of flood those dams disappear entirely and leave the bed of the canal free for the passage of the water. If flushing is not sufficient to keep the canal clear, the system of automatic dredges can be adopted (*vanages*), with certain success.

As we have stated before, in order to properly distribute the waters in the valley, a whole system of canals of small dimensions has been studied, measuring in all, the great canals included, more than 250 miles in length. Toward the south the feeders will be the fountains of the lakes Chalco and Xochimilco. Toward the north the river of Cuautitlan and the Lake Zumpango will furnish the necessary water. In the centre part Lake San Cristobal will do the same office. Besides, the canals will receive on their passage all the waters of irrigation, to deliver them afterwards at the spot where they are needed. By means of all those lakes the whole valley will be circumscribed at different levels, following the fall of the ground.

The waters that will escape through the great tunnel out of the val-

ley, as well as the sewerage of the city, will be most advantageously employed on the lands of those regions to the north that are barren largely for want of water, but most fertile where the precious liquid can be obtained.

Gentlemen, I might continue for a very long time without exhausting my subject, but I must put an end to my speech, being ready to answer any questions that may be put to me. One word only with regard to cost. My whole project I estimated some years ago would cost 10 000 000 dollars; one-half of that sum for the drainage or *desagüe* proper, and the other half for the canalization. To-day, on account of the great demand in Mexico, hand labor is rapidly increasing in price, and that must be taken into account in new calculations.

The works of the *desagüe* are now momentarily stopped, but the Government of Mexico made last year a contract for the construction of the works with Mr. Antonio Mier y Celis, and, taking into consideration the respectability of that person, his great monetary resources, and the confidence that he enjoys in our Society, as well as the credit that his powerful and respectable circle has near the men in power, there can be but little doubt that he will be able to realize a scheme that may or not increase his fortune, but that will surely shower upon his head the blessings of all the inhabitants of the Valley of Mexico.

The Hydrographic Map of the Valley of Mexico (Plate XIV.) accompanying Paper CCLVI. shows the position of the City of Mexico, of the several lakes described in the paper, the lines of the ancient cut at Nochistongo, and the lines proposed for drainage conduits.

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CCLVII.

(Vol. XII.—May, 1883.)

DISCUSSION

ON THE INCREASED EFFICIENCY OF RAILWAYS FOR THE TRANSPORTATION OF FREIGHT.*

PAPER CCXLVIII.

By WILLIAM P. SHINN, M. Am. Soc. C. E.

DISCUSSION

By O. CHANUTE, M. Am. Soc. C. E.

O. CHANUTE, M. Am. Soc. C. E.—In accordance with the promise made on a former occasion, I now beg leave to present some considerations upon Mr. Shinn's paper, which have occurred to me since I have had leisure to read it more carefully than was possible in the first looking over of the original proof-sheets.

I shall say nothing concerning the first part of the paper. The rapid increase in the efficiency of railroads in this country has been so well stated by Mr. Shinn, and he has so thoroughly explained the means by which it has been brought about, that he has left but little for others either to glean or to controvert.

* Transactions Am. Soc. C. E., Vol. XI., p. 365, November, 1882, and Vol. XII., p. 126, April, 1883.

Concerning, however, the diminished efficiency in movement of freight cars, which the author notices, and the remedies which he proposes, some doubts have occurred to me, which may be worth stating.

I think it is worth inquiring whether the diminished average mileage obtained from cars is an unmixed evil, and whether there have not been changes in the general mode of transacting business which, while they require a greater standing still of the cars, yet add materially to the economy of trade, and to the convenience of the customers.

I grant that the figures given by the author seem at first sight alarming. He has shown that on the Pittsburgh, Fort Wayne and Chicago Railroad there has been a decrease of 21 per cent. in the number of miles daily run (on an average) by each car, from 1868 to 1881; that the "Union line" cars averaged 38 per cent. less miles per day in 1881 than they did in 1876; and he has stated some reasons, as given by the railway managers (which do not seem entirely satisfactory), for this diminished efficiency.

It is worth while to inquire whether this is not offset by either a more efficient loading of the cars, by the decrease of their empty mileage, or by savings effected in the business of the country at large.

Thus Mr. Shinn's own figures show that in 1868 the mileage of empty cars on the Pittsburgh, Fort Wayne and Chicago Railroad was 17.4 per cent. of the whole, while in 1881 it had been reduced to 13.2 per cent.; and clearly, if by holding the cars at the stations they were sent back loaded instead of empty, that cannot be called a decrease in their efficiency.

Again, the accommodation of the customers is (or should be) the primary object with railroad managers. If expense can be saved to the owners in receiving or disposing of property in transportation, it enables them to pay a better freight rate, and so conduces to the advantage of the railroad. In the good old days, when interest was high, cars very scarce and depots small, there were good reasons why cars should be kept constantly rolling. The customers had to beg for them, to load them in haste; and as soon as they were received at their destination, the consignee had to haul the goods away in wagons, handle them into his warehouse or cellar, and store them until a market was found for them. When disposed of, either for distribution to the surrounding country or for export, he had to handle them out again, haul them back to the depot of some transportation line, perhaps to the very one where he first received them, and ship them away to the consumer.

Now, on many classes of property, this needless double cartage and handling is largely done away with by the improved system which has come into use, of holding the goods at the point of production, and shipping them when wanted direct to the consumer.

Perhaps the examination of a few individual cases will be more convincing than mere abstract statements. Let us therefore inquire what changes have taken place in the methods of handling dry goods, woolens and other textile fabrics which go to clothe the people.

Twenty years ago, almost the whole of the product of such fabrics, as fast as produced, came to a few Atlantic cities for disposal. The goods went into the stores of the jobbers, and were thence distributed all over the country. The shipments from the mills were therefore regular, and there was such concentration of freight at the jobbing cities, Boston, New York, Philadelphia, etc., as to furnish that regularity in business which is most conducive to the maximum movement of a given number of cars. This method, however, involved a double handling and draying at the points of distribution, and much rearranging and repacking of the goods in the stores of the jobbers.

Now, as I believe, very much of the jobbing trade has gone to the interior cities. Their merchants keep buyers in New York, and to this point the manufacturers, instead of sending all their goods, send an agent with samples to solicit orders. When these are given in sufficient volume, the goods are shipped direct from the mill to the western merchant, and by him distributed to the surrounding country. It is evident that this method effects a saving to the trade, but that it requires the distribution of many more cars than were formerly needed through the manufacturing districts, and the detention of these cars at the mills while waiting for shipping orders.

Conversely, when the cars loaded with these goods arrive in the West, if an immediate return load is not found, the choice is offered to wait for one or to send them back empty.

Let us see what happens, say in the provision trade—beef, pork, bacon, lard, etc.—a large and profitable branch of our national exports. In the good old days, when cars were scarce and their movement active, the packers in the West shipped their product nearly as fast as it was manufactured. It went into stores in New York, Brooklyn and other points, and there awaited customers. This involved double lightering, carting and handling.

Now, much of the product is kept in the West until it is ascertained whether it will be sold in California, Texas, New York or Liverpool. If the latter eventuality occurs, the English merchant cables to his correspondent in New York; this agent then charters the freight on some steamer or sailing vessel, and telegraphs to the western packer, who calls on the railroad for the waiting cars. The provisions are then shipped with a through bill of lading to Liverpool, and are, upon their arrival at New York, lightered directly to the vessel, thus transacting the business at a minimum of expense, notwithstanding the idleness of the freight cars while awaiting the occasion.

I have been thus—shall we say tedious—in making a point which might have been stated in a few words, because I wanted to make it clear, and because we are all too apt to look at a subject from a single point of view, and to assume that what is best for the interest we serve is going to be best all around.

Of course, it is very desirable to obtain the utmost service, in the way of mileage, which can be got out of freight cars, but if, by so doing, the cost of the other portions of the business of the customers is materially increased, they will not be able, limited as they are between the commercial value of a commodity at the point of production and at the point of its consumption, to pay the railroads as good rates of freight as they would otherwise afford.

Now, I do not say positively that this is so in the case under consideration, but I do say that before accepting Mr. Shinn's conclusions, that the diminished daily average movement of cars indicates bad economy and management, it is worth while to investigate whether it does not result from a change in the modes of transacting business which is beneficial to the country at large; and whether, if the present facilities be curtailed, it will not be necessary to make corresponding reductions in the freight charges "which the shipments will bear."

Two points of possible railroad economy, which seem to me important, have been omitted by Mr. Shinn. The first is the needed reduction of the empty mileage of cars to a minimum. From the figures which he gives for the Pennsylvania Railroad for 1881, I deduce that 33½ per cent. of the freight cars run empty, and I have reason to believe that some of the other trunk lines do even worse than this. This empty mileage costs money and brings in no revenue. It costs nearly as much to haul an empty car as a full one, and I believe that by designing and managing the cars (coal, cattle, petroleum) so that they can be loaded

back, and by having a sufficient number to enable them to wait for such back loads, as has been already indicated, the empty mileage may perhaps be reduced to a smaller percentage than it is now.

Another possible important economy is likely to result from the establishment of large warehouses at terminal points. At present the need for this is so great that the railroads cannot provide sufficient terminal depots to accommodate their customers. They are compelled to hold goods from five to thirty days, until they have been disposed of in some way, either by sale, or chartering of some vessel to export them, or otherwise. The worst of this method is that it not only operates unequally and unjustly, but the railroads do not receive compensation for the storage which they furnish. If this public demand were met by an organized effort to accommodate it more fully, and the railroads either built or promoted the building of large public stores and warehouses in close connection with their terminal arrangements, the customers might be saved double cartage on all consignments which did not enter into immediate consumption, and might be given time to dispose of the property to the best advantage (which sometimes they are not), while the railroads would receive fair compensation for such storage as they did furnish (if they owned the warehouses), and would also secure a prompt unloading of their cars.

Each road, however, will have to work out these and similar reforms for itself, in view of all the surrounding circumstances, so as to accomplish the best economical results. I simply mention them now to attract the attention of those who may be interested in further railroad economies.

With respect to the detention of freight cars on "foreign roads," and the methods of paying for their use, I quite agree with Mr. Shinn that there are serious defects in the present system of "mileage charges," but as he has not stated a specific plan, I wish to mention some general objections which occur to me as applying to the "per diem charges" which he proposes to substitute.

In the first place, it is not unlikely to lead to a considerable increase in the mileage of empty cars. The terminal road, after receiving a car and unloading it, will be very apt to return it empty, instead of holding it in the hope of finding a load. This it will do to save the per diem charge, and especially if it has only a short haul to make to get rid of the car. In the latter case, a considerable hardship may be inflicted

upon the next road, if it chances to have a long haul upon this empty car, which thus becomes a source of expense and earns no revenue. This clearly is not good economy; for increased movement of freight cars is desirable only when they carry loads.

Secondly. In the absence of a specific plan, I do not see very well how the per diem charge is going to follow the car over the different roads over which it passes, so as to afford any check to its owner. It is, we will say, delivered to road A, which passes it over to road B, and the latter delivers it to C, and so on. When it comes back, and this perhaps over a different line than that to which it was originally delivered, the owner of the car, doubtless, knows how many days it has been away in the aggregate, but how will he be able to apportion those days, if some of the roads have omitted to report, or have made mistakes in reporting the time the car was on their line? At present, by the mileage plan, the road owning the car has a check—a rough one, to be sure—upon the reports which it receives. If it loads and bills a car for a distant point, it knows from the distance tables how many miles it has to go over each road forming the line, but it cannot tell how many days each road takes in hauling that particular car. One important defect in the present mileage charge, to be sure, is that a car can be used in local traffic without being reported, and the owner has no check to show this, but the very fact that he has a check over the aggregate number of days, when a per diem charge is substituted, may lead to great vexations and disputes, and necessitate an elaborate and expensive system of checking the delivery of cars—in fact, a car clearing-house.

Perhaps, with the growing and inevitable consolidation of our railroad lines into great systems, and the consequent decrease of parties with whom each road has to deal, much of these objections will disappear. When but one or two, or even three, roads have to be settled with in apportioning the per diem charges on a car, it will be a much simpler matter than it would have been thirty years ago, with five or six roads in each line between New York and Chicago.

Thirdly. There is the probable increased expense in keeping the accounts if a per diem charge is substituted for the present mileage system. I believe the car accountants, who have repeatedly had the subject under consideration, are satisfied that a clearing-house will be necessary, and that the clerical labor will be greater than that now required.

Fourthly. We must take some account of the probable opposition to the proposed change. This will arise from at least two sources: first, from those roads which profit by the imperfections of the present system, and which will threaten to turn their business away from the roads which attempt to inaugurate a reform; and, secondly, from that general feeling of conservatism which opposes all changes. If, however, a good and equitable plan is presented, and it is shown to be superior to the present method, the opposition to a change can and should be surmounted.

Fifthly. In elaborating such a plan, account should be taken of the inevitable temporary confusion which results from a change of methods, and also of the various hardships which are likely to arise in unforeseen cases from the application of general rules. For instance, the question will come up as to who is to pay the per diem charge in case a road which is offered a car loaded for some point on its line refuses to receive it, either in consequence of a temporary freight blockade, or because it claims that the car is not in good repair, while the delivering road claims that it is in running order. Again, how much is to be paid per diem if a car is wrecked upon a "foreign road," and has to be rebuilt, a process which I have known to occupy six months or a year? In this case the road owning the car, perhaps an old one, will get a new car and a handsome per diem for the worn-out vehicle it passed off upon its neighbor. And again, what shall be the minimum charge to a road having a very short haul, which occupies less than a day? I know several instances in which roads have only from six to twenty miles haul upon considerable volumes of traffic, and insist upon doing the business themselves, instead of granting a running right. They will probably object to paying for a whole day if they do the work in two or three hours. I might also ask how the per diem is to be computed upon a "lost car," but that is an exceptional case, and the hardship is the same under the present mileage system.

I mention these objections, not as insuperable obstacles to the reform which Mr. Shinn proposes, but to show that before it can be carried out, he has to do a good deal more than merely to suggest it. He must, in fact, present a well-matured plan, and show how it is going to work. This must be simple, and in sufficient detail to provide for all ordinary cases, and for some of the contingencies likely to arise. The organization at junction points and in the general offices should be

indicated, as well as the rules which shall govern in inspection of cars and in accounting.

I hope that Mr. Shinn will indicate his views and plans fully in summing up the discussion on his paper, for the reform which he advocates is important, and although, as he says, the proposal is not new, I believe no attempt has hitherto been made to reduce it to practice, chiefly for the want of an adequate plan.

Now, concerning the last and very important point, as to what the per diem charge shall be, I should like to say a few words. This question is likely to bring out great divergence of views, and until it is settled there does not seem much hope of getting the change in system adopted. It will be seen, for instance, that I figure up the fair charge per diem at only about one-quarter of that proposed by Mr. Shinn, and doubtless others who may discuss his paper, and especially the railroad managers, when they come to consider the per diem charge in the practical light of their respective interests, will entertain still different views.

Mr. Shinn proposes a charge of one dollar per day, and he thinks this to be a fair charge, because it represents about the earning capacity of cars upon the roads with which he is most familiar. He defends it upon the ground that a company which has secured an adequate supply of cars is entitled to their use or its value.

I think $1 per diem altogether too much, because it yields very much more than the interest upon the cost of a car, its depreciation and cost of repairs; and I submit that, in fixing a general rate for car service, the object should be not so much to obtain large profits when cars are in demand, as to promote the current interchange of business without unnecessary reloading of cars, and on terms equally fair to all roads.

Let us see what car service is reasonably worth on this basis. Freight cars of various classes cost on an average about $550 each, and the yearly interest on this, at 6 per cent., is $33 a year. At 7 per cent. it is $38.50 yearly. In addition to this there is the cost of "car maintenance," which includes current repairs, renewals to cover depreciation, and rebuilding of cars to keep the number good. On the New York, Lake Erie and Western Railroad this averaged $40.92 per freight car for the five years preceding 1882. It averaged $69.01 per freight car for 1881 upon the Pennsylvania Railroad system, including the United Railroad of New Jersey and the Philadelphia and Erie Railroad. On the Pennsylvania Railroad proper it averaged $66.51 per freight car for the year 1881.

Now, on the basis of 7 per cent. interest, and the cost of maintenance on the "Erie," the annual charge is $79.42, or some 22 cents a day, and on the basis of 6 per cent. interest and cost of maintenance on the "Pennsylvania system," the annual charge is $102.01, or some 28 cents a day per car. We must bear in mind in addition that each road is bound to keep the car in current repair while on its line, so that it seems to me that a per diem charge of 25 or 30 cents a day would be a fair one all around, in the general exchange of business. If made 35 cents a day it would pay the cost of maintenance on the basis of 1881 on the "Pennsylvania system," and nearly 11 per cent. interest.

In my judgment, the attempt to charge $1.00 per day for the use of freight cars in the general exchange of business would be pretty sure to defeat itself. The roads with limited rolling stock would resort to various devices to keep the "per diem" at a minimum, such, for instance, as refusing to receive cars, under various pretexts, until they were prepared to haul them directly through; providing their own cars into which to reload the goods at junction points; holding back shipments until they can procure cars from some rolling stock company, which, as Mr. Shinn says, hire out cars for $15 a month, or 50 cents a day, &c.; all of which will tend to bring about freight blockades and much wrangling.

I believe, therefore, that in order to make the change which Mr. Shinn proposes acceptable, it will be necessary not only to present an adequate plan, but also to make the basis of the per diem charge so eminently equitable that it will be generally acquiesced in; and how this shall be done will, I hope, be indicated by the author in closing the discussion of his paper.